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TEACHING THE PHYSICS OF MEDICAL IMAGING: AN ACTIVE LEARNING APPROACH INVOLVING IMAGING OF BIOLOGICAL TISSUE

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Abstract

Introduction to medical imaging is an experimentally oriented course in the physics of medical imaging, where the students record, process and analyse 3D data of an unknown piece of formalin fixed animal tissue embedded in agar in order to estimate the tissue types present. Planar X-ray, CT, MRI, ultrasound and SPECT/PET images are recorded, showing the tissue in very different ways. In order for the students to estimate the tissue type, they need to study the physical principles of the imaging modalities. The "true" answer is subsequently revealed by slicing the tissue.

Keywords: Imaging phantoms, fiducial markers, X-ray, ultrasound, MRI, CT, teaching, education, learning.

1 INTRODUCTION

This paper shortly outlines a course in the physical principles of medical imaging, where the students actively participates by being responsible for scanning a box with unknown biological tissue (a so-called phantom), interpreting the images and finally predicting the kind of tissue on the image. The present paper deals with the aspects of comparing ultrasound, computed tomography (CT) and magnetic resonance (MR) images. More details on this approach can be found in [1], which also treats planar X-ray and SPECT. A macroscopic picture of the anatomy is subsequently obtained by slicing of the tissue.

The course is held in the autumn term (September to December) at DTU and is mainly designed for the students in the education Medicine and Technology (a Bachelor/Master's education taught in collaboration with the Faculty of Health Sciences, University of Copenhagen).

The present paper is mainly aimed at those involved with teaching in biomedical engineering.

Figur 1 The phantom consisting of biological tissue moulded into agar and surrounded by an acrylic mould. The tube is for PET investigations which are not considered here.

2 MATERIALS AND METHODS

All the tools and materials used in this course are presently custom made. The medical images at the hospital are made with standard equipment.

2.1 Phantoms

Each phantom is made from a piece of formalin fixed animal tissue possibly containing lipid-rich tissue, muscle, cartilage and bone. The tissue sample is moulded into an 105 by 75 by 35 mm agar block containing fiducial markers on the top, which can be recognized by the imaging techniques used and later by the students, when slicing the agar block. An example is given in Figure 1.

By means of small pins at the bottom of the acrylic moulds (and corresponding holes at the top), the phantoms can be stacked reproducible in various ways, to facilitate data extraction, in cases when all phantoms are scanned at the same time.

2.2 Course flow

The course runs once a week over 13 weeks during a DTU afternoon module from 13 hours to 17 hours. Two such modules are used for the scannings at the hospital and one is used for the ultrasound scanning at the university (since we have this equipment available).

Photograph of top of phantom: The top of the phantom is scanned with an optical flat bed scanner to obtain a metric photograph, showing fiducial markers, the shadow of the tissue and the binary ID (which is barely visible at the bottom of the surface in Figure 1).

The students load the photograph into a special software program developed by the first author of this paper (SIS) and ensure that the metric axis and units are correctly shown. The students also have to choose a zero-point on the photograph, in order to calibrate all subsequent data sets to this zero-point. When all images have the same coordinate system, it becomes possible to match the images for comparison.

CT scanning: A 3D CT scan is performed with the phantoms stacked. From the 3D data of six phantoms, the students extract the 3D data set representing their own phantom. From the extracted 3D data set, a view of the surface can be extracted showing the fiducial markers. This in turn leads them to identify the zero point and thus later extraction of the slice of interest. An example is shown in Figure 2.

MRI scanning: The MRI scan is also performed with the phantoms stacked. The MRI data are handled the same way as the CT data. For didactic purposes, it can be beneficial that all students at the hospital are allowed close to the scanner under strict enforcement of the normal access procedures involved, thus demonstrating the important safety aspects of working with large (super conducting) magnets. An example is shown in Figure 2.

Ultrasound scanning. Each team of four students gets a 30 minutes time slot for scanning their own phantom with 3D ultrasound, by means of a special mini scanning tank that can hold the transducer for manual linear translation. About 60 images (forming a 3D data set) are recorded. An example is shown in Figure 2.

Slicing of the agar block. In order to obtain a golden standard, an anatomical cross-sectional photograph is created. For this part, the agar block is extracted from the mould. The plane to be investigated is identified from the surface of the agar block (typically this will be through a fiducial marker). The agar block is sliced to extract both sides of the plane in question. The two tissue slices are placed on a transparency sheet and scanned on a flat bed scanner. An example on one of the sides is shown in Figure 2.

2.3 Challenges faced by the students

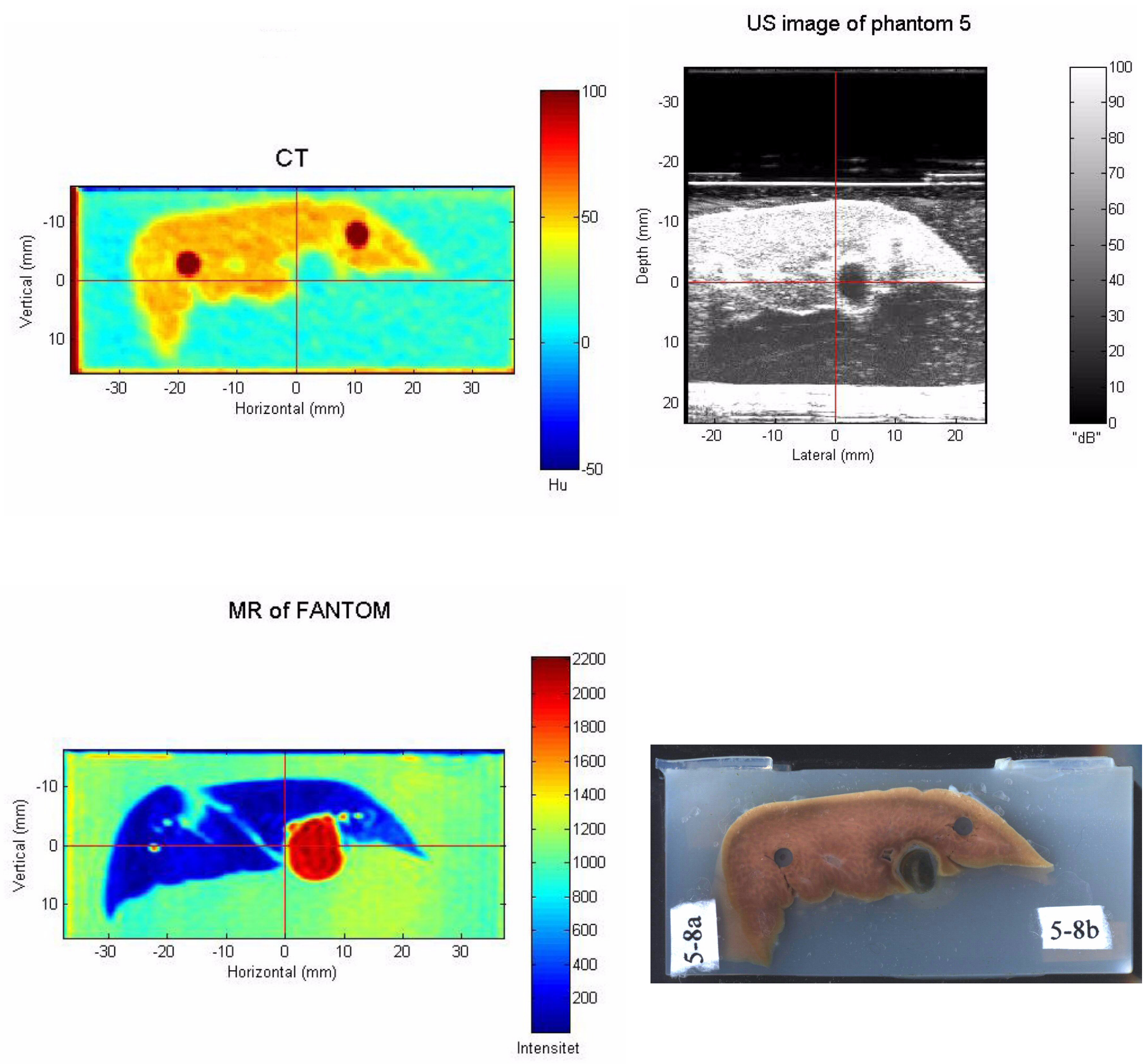
When all image data have been collected, isolated and calibrated for the correct zero-point, each team selects a slice in the tissue for thorough analysis. An example of the corresponding CT, US and MRI images for such a slice can be seen in Figure 2. The challenge to the students is now to identify as much as possible of the tissue presented in the images. For this purpose they need to know:

- Which tissue parameter(s) that are imaged together with how a given type of tissue appears on a given imaging modality.
- Which artefacts that can typically be present, and how they influence the image.

One of the main challenges for the students is, that exactly the same tissue often will look quite different on the different imaging modalities. When knowing which parameter(s) the images show, and which artefacts that can be present, the student can deduct (or at least estimate) what is present in the scan plane they have selected. This requires, however, that the students understand the basic theory of the physical principles of the imaging modality.

The central sets of images that are to be compared are the CT, US and MRI images in Figure 2, which are shown for the same scan plane. Some of the relevant questions can be:

- Why does the US image show apparently homogeneous tissue in different ways?
- Why does the plastic tube appear different on the different images?
- Why are the CT and MR images free of angle-dependence, but not the US image?
- Does the pixel value of the image reveal any absolute measure of a physical quantity?
- What kinds of tissues are present on the image? Does they appear as they should on all images?



Figur 2 Spatially aligned images produced by CT, ultrasound, MR (T_2-weighted) and anatomical photograph produced by slicing of the phantom.

3 CONCLUSIONS

The course appears to be a success on most accounts: high increase in competencies subjectively judged from graded reports, low course drop-out rate, high pass-rate at the exam, high student participation and large student satisfaction. This use of human resources is moderate to high.

4 ACKNOWLEDGEMENTS

All members of Team 5 of 2007 are acknowledged for the work of producing Figure 2. Instrument maker Kjeld Martinsen is acknowledged for the tedious work of producing the phantoms year after year.

5 References

[1] J. E. Wilhjelm, M. Pihl, M. N. Londsdale & M. Jensen: An active learning approach to the physics of medical imaging. Medical Engineering and physics. 2007. In press.